A Comprehensive Decision Approach for Rubber Tree Planting Management in Africa·

(Revised Version 2)

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Abstract:

The main objective of this study is to settle a rigorous field of decision analysis for rubber tree clones selection. Nowadays there does not exist any process based upon a rigorous method to select the best clone to be plant in order to get the highest return on investment. The only known selection method is to use the experience of different protagonists acting in the plantation. So, we need a tool that takes into account very important criteria in order to achieve the main objective. This goal is achieved by using multicriterion analysis methods to the clone selection. The ranking procedure uses ELECTRE III. For each criterion, indifference and preference thresholds are determined after establishing the relative importance of each criterion including rubber tapping, cumulative production during 15 years, cumulative production between 15 and 25 years, wind resistance, disease resistance, physiological resistance, grafting, quality of the rubber tree.

Keywords: Multicriteria decision making, Rubber tree, Agricultural resource management

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1. Introduction

Rubber tree[5] is one of the world's important crops, with 8,000,000 ha under cultivations. This tree is the original source of natural rubber, one of the few industrial raw materials produced with beneficial economic and ecological impact[6]. Rubber tree has become a development instrument for developing countries and a good way to fight against deforestation and soil erosion, critical problems in tropical countries. It reduces human pressure on natural forests by supplying an excellent timber. It has remained the only tree capable of supplying natural rubber abundantly enough to support the world's growing demand (natural rubber is a significant element for tire industry[7]). The two centres of rubber tree crop are located in south east Asia (Thailand, Indonesia, Malaysia) where natural rubber production takes place with more than 92% of the world production, and in Africa (Ivory Coast, Nigeria, Gabon, Liberia…) where production is only 5% but with a comparative advantage in term of lands and labour forces. This advantage has allowed Africa significantly develop this resource since 1970's.[8] The selection program carried on by the world's rubber-producing countries for developing high-yield clones has constituted one of history's largest international cooperative.

The development of rubber tree cultivation in Africa is the result of public and private initiatives. The final decision is the result of interaction between different decision makers like agronomists, small farmers, agro-industrial firms or public institutions (public research centre). The growing influence of small family farms in the rubber tree plantations (80% of 8,000,000 ha under cultivation) leads to a redefinition of selection aims and a shift in priorities towards clones that are less sensitive to exploitation vagaries (Lançon *et al*. 2006). Supplying small farmers with efficient clones will allow ensuring a high return on investment, preserving plantation against wind and leaf diseases and ensuring a long term stability of plantations. The public and private institutions involved in selection programs are increasingly faced with a demand for varieties adapted to sets of constraints (financial, ecological...).

The selection program was twofold: On the one hand select clones from Asia and, create a new category of clones in Africa (called IRCA) on the other hand. Since 1964, in order to get agro-economic information on the best clones among a family of 130, agronomists have developed[9] a huge network of study. Despite this vast study, a problem remains. There is not enough information about the behaviour of the rubber tree clones with respect to environmental constraints like weather, state of the soil, diseases, etc. Based upon the different places where the rubber tree plantations are located, the production can be very different. So the best plant at the right place is a *sine qua non* condition for a

[5] See Compagnon P. (1986) for a description of rubber tree.

[6] The rubber tree crop is a long-term investment because rubber tapping begins between 5 and 8 years after planting, and lasts on a period of 20 to 30 years.

[7] In fact, 70% of the global production goes to this industry.

[8] Having in mind that this production does not compete with the food for locals.

[9] Mainly in Ivory Coast but also in Nigeria and Cameroon.

good production of natural rubber. For a given site, it is also necessary to diversify the type of clones in order to reduce the risk. The question we are raising is the following: How can we get the most efficient clones in order to get the best output in a period of time ranging from 6 to 25 years?[10]

Over the past decades, studies on different topics have been done and methods based upon multicriteria decision analysis have been developed for purposes of natural resources planning (Georgopoulous *et al.* 1997, Hokkanen *et al.* 1997a, 1997b, Diaby *et al*. 2010), urban stormwater drainage management (Barraud *et al*. 1999, 2004, Martin *et al*. 2007).

The main objective of this study is to identify the rubber tree clones that provide the best economic output over 15-25 years of exploitation. In the following sections, we present the selection criteria, the application of the multicriterion method ELECTRE III and finally the results obtained.

2. The evaluation of criteria for the selection of rubber tree clones

2.1 The rubber tree clones

Rubber tree is reproduced under shape of clone by agronomists in order to get a homogeneous and high productivity in plantations. Allowing small farmers to get high-performance clones is a priority for some developing countries. Indeed, the rubber tree provides to small farmers a monthly income during about twenty or thirty years old. All trees in plantations of Thailand, India, Guatemala or Ivory Coast practically are clones (Sainte Beuve *et al*. 2001).
The goal of our study is to rank 30 clones from the best to the worst according to our criteria. This allows us to make recommendations to the decision makers in charge of the rubber tree crop. Each of 30 clones is the object of a synthetic description in the document "brief characterization of the clones of rubber tree in Ivory Coast," published by A. Clement-Demange in 2007.
Seven main clones under cultivation, called GT1, PB217, PB235, PB260, PR107, RRIC100 and RRIM600, were studied in past; these are the best known and constitute a reference sample for the study of the other clones. 18 clones called IRCA were created and selected in Ivory Coast from 1974's. Clones called PB330, PC10, RRIM703, RRIM712 and RRIM802 are clones created in Malaysia.

[10] This is the time for the exploitation of a given plot. Moreover, information on the clones' behaviour is generally collected during the fifteen first years after planting, while the economic life of a plantation is 25 years or more. During this period, clones behaviour is fully observed with respect to local constraints (wind, soil etc.).

2.2 The criteria

Criteria are selected so that they are fully understood and accepted by rubber tree crop stakeholders (small farmers, industrials or developing countries). We have realized this task in cooperation with an agronomist. The choice of clones is important for technical and economical success of a plantation. This choice must be done according to production potential and according to the behaviour of clones facing other characteristics (diseases, wind, etc.). These criteria were selected in order to ensure a high return on investment (Open, P15 and P25), to maintain the tapped trees' population (Wind, TPD and DL) and to resist to diseases (Col, Cor and Oïd). Others criteria tied to rubber output such as physiological resistance, grafting and rubber quality were included in this study.

The rubber production is the dominant objective, far in front of the production of the wood of rubber tree, in particular in Africa. But the necessity to take into account the financial updating of the results (evolution of the value of receipts and the expenses in time according to the interest rate of the money) makes that the productions of the first years have an economic value much greater than that of the productions of the later years.

Rubber tapping is realized when at least 200 trees (about 40% of the plantation) have a circumference of the trunk around 50 centimetres to 1 metre above the ground. Hence, the strongest clones start to produce at the age of $4^{1/2}$ years old in the favourable ecological conditions of the south of Ivory Coast.

The productivity depends on the genetic potential of clones but also on the ability of the tapper. The number of tapped trees by hectare tends indeed to decrease in time because of the damages due to the wind. Among many clones selected for their high productivity, a small group have a good resistance to breakage. But this concept of resistance remains relative because in some areas, the wind can be extreme. Another problem is related to the emergence of necrosis of the bark, which leads to stopping the flow of latex during tapping. It does not lead to the death of the tree but reduces significantly the performance of plantations. These phenomena of coagulation and necrosis are pooled under the same term of TPD (Tapping Panel Dryness). A biochemical diagnosis realized on the latex (latex diagnosis) allows characterizing the biological performance of the phloem[11], in connection with the early production capacity, the late production capacity and the sensibility in the TPD.

In Africa, two diseases of leaves, namely the *colletotrichum* and the *corynespora* are important to consider. The *oïdium*, another leaf disease, has a weak incidence (*oïdium* affects the young leaves at their first stage of development and leads to important defoliations on the grown-up trees at the time of the refoliation). Mushrooms appearing generally on the leaves of the young trees cause *colletotrichum* and *corynespora*. They affect tissues damaged by external causes (the light, the sun, etc.) or bad conditions of vegetations (drought); and lead, if the tree is not treated, to a full destruction of the tree.

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[11] Tissue in higher plants that conducts synthesized food substances to all parts of the plant.

Various techniques (not presented in this document) are used to treat these diseases (Delabarre and Serier, 1995).
Some clones have weak rates of success to the grafting, but this aspect is of little importance in the choice of clones. Rubber tree supplies an excellent timber and contributes to the reforestation. The technological quality of the rubber was a quite few studied element but recent studies tend to prove the contrary. Natural rubber remains a composite with very variable technical characteristics. Before 1965, the criteria used to evaluate the quality were only visual (RSS: ribbed smoked sheets or ADS: air dried sheets). After 1965, physical and chemical criteria were provided (TSR: Technically Specified Rubber)[12]. Thus, buyers have a large variety of quality and presentation of natural rubber (Sainte Beuve *et al*. 2001).

We may add the following remark. A supplementary factor for the choice of clones is due to the fact that the old clones are much better known than the recent ones. In order to reduce risks, the decision-makers of plantations prefer to use old clones probably less efficient than some more promising and more recent. In fact they try to manage the biggest part of their plantations with old clones but they keep a small part with recent clones in an R&D vision.

2.3. Analysis and evaluation criteria

This section is devoted to the analysis of the criteria and their influence on the rubber production. A criterion is a tool that allows two different actions to be compared. And the choice of the criterion is related to the problem raised by the decision maker. Then 12 criteria should be considered before choosing between the clones.

2.3.1. The 12 criteria of evaluation

Open	growth speed immature and precocity of tapping (in months)
P15	cumulative production of latex to 15 years (in kg/ha)
P25	cumulative production of latex between 15 and 25 years (in kg/ha)
Wind	wind resistance, breakage of the trunk and uprooting (resistance mark)
TPD	notch dries and necrosis of bark (resistance mark)
Col	tolerance of leaf in *colletotrichum* (resistance mark)
Cor	tolerance of leaf in *corynespora* (resistance mark)
DL	latex diagnosis (mark of physiological robustness of the phloem)
Timb	volume of rough timber (importance mark)
Graf	success in the grafting (success mark)
Oïd	tolerance in *Oïdium* (resistance mark)
Tec	the technological quality of rubber (quality mark)

[12] The proportion of different forms of rubber produced worldwide in 2001 is as follows: TSR (55%), leaf (30%), latex concentrate (10%) and miscellaneous (5%). TSR 20 Rubber is the most used by the tire industry.

2.3.2. Criteria evaluation

Data are estimates on the behaviour of clones under different criteria. The period of exploitation will be linked to the development of tapping (opening of GT1 in 66 months or $5^{1/2}$ years). This criterion is the only whose weak values are considered as favourable and are preferred to the high values.

The cumulative production over 15 years result from a global analysis of 44 trials with for every year of production (from 6 to 15 years) an adjustment of the annual production of every clone by the ordinary least square statistic. For every clone, the adjusted annual productions are then determined in order to provide a datum of accrued production in 15 years (in kg) of dry rubber by hectare.

All other data are "expert's marks" established between clones from all the known information. In order to avoid redundancy among the criteria we implement, from the matrix, a principal component analysis (table 1).

Table 1: Evaluation matrix (12 criteria and 30 clones)

Clones	Open	P15	P25	Wind	TPD	DL	Col	Cor	Oid	Tech	Timb	Graf
Units	months	kg/ha	kg/ha	1…10	1…10	1…10	1….5	1….5	1…5	1…5	1…5	1…5
Trend of parameter variation	↓	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
GT1	66	14516	19782	5	5	7	1	4	3	2	2	5
PB217	72	16240	28553	9	8	10	1	2	3	1	3	1
PB235	54	18835	15000	1	1	1	3	2	1	2	5	3
PB260	63	18702	15000	1	1	1	5	1	3	3	4	3
PR107	90	8556	30000	10	10	8	2	3	3	5	3	3
R100	57	17473	20000	7	5	4	5	5	3	2	4	1
R600	72	13480	21829	7	5	3	3	1	5	3	1	3
I18	66	18105	20000	5	6	2	1	1	3	2	3	3
I19	62	14823	22000	5	8	8	4	3	3	2	4	3
I41	64	17403	26000	7	8	8	1	2	2	3	3	1
I101	64	19496	23000	6	4	4	2	2	3	2	3	3
I109	63	18158	20000	4	6	6	2	2	3	2	4	3
I145	64	17864	18000	4	3	3	2	2	3	2	2	3
I209	62	17380	18000	5	4	2	2	2	3	2	2	3
I230	57	22477	20000	5	5	4	2	1	3	2	4	3
I317	60	21448	20000	5	2	2	2	2	3	2	4	3
I323	66	15739	22000	6	3	8	2	2	3	2	3	3
I331	66	23467	23000	6	5	8	2	2	3	2	3	3
I427	66	18125	23000	6	7	4	2	2	3	2	2	3
I428	64	17745	23000	5	7	6	2	2	3	2	2	3
I523	62	19654	23000	5	2	3	2	2	3	2	3	3
I631	66	17476	20000	1	5	4	2	2	3	2	4	3
I733	62	19580	18000	3	2	4	2	2	2	2	5	3
I804	64	21181	15000	1	5	3	2	2	3	2	4	3
I840	64	19339	20000	6	3	3	2	2	3	2	3	3
PB330	62	18300	17000	1	3	6	1	2	3	2	5	3
PC10	64	16629	23000	6	2	3	2	2	3	2	3	3
R703	66	19908	15000	2	2	1	1	2	3	2	2	3
R712	66	16559	25000	8	7	4	1	1	3	2	2	3
R802	64	19150	23000	6	5	8	2	2	3	2	3	3
Min	54	8556	15000	1	1	1	1	1	1	1	1	1
Max	90	23467	30000	10	10	10	5	5	5	5	5	5

⇑ means that performance of the clone with respect to the specific criteria increases as the criterion value also increases.

⇓ means that performance of the clone with respect to the specific criteria decreases as the criterion value increases.

2.3.3. Criteria analysis

This analysis of the relations between the criteria indicates a strong redundancy between the criteria P25, wind, TPD and DL (figure 1). In particular, the production P25 (cumulated production between 15 and 25 years) is strongly explained by the 3 criteria wind, TPD and DL. Indeed these 3 criteria are explanatory factors of the resistance of clones in the erosion of the number of tapped trees by hectare along a period of time. For this study, we thus decide to eliminate the criterion P25, not because it is not important but because it is directly measured and correctly predicted by the 3 criteria wind, TPD and DL.

Table 2: Correlation matrix between the criteria

Criteria	Open	P15	P25	Wind	Tpd	Dl	Col	Cor	Oid	Tech	Timb	Graf
Open	1	**-0,69**	**0,61**	**0,53**	**0,56**	0,40	-0,25	0,01	0,38	**0,65**	-0,41	0,03
P15	**-0,69**	1	-0,48	-0,47	**-0,50**	0,34	-0,05	-0,30	-0,25	**-0,58**	0,32	-0,02
P25	**0,61**	-0,48	1	**0,88**	**0,71**	**0,68**	-0,25	0,09	0,18	0,28	-0,34	-0,33
Wind	**0,53**	-0,47	**0,88**	1	**0,61**	**0,51**	-0,14	0,18	0,30	0,25	-0,49	-0,32
Tpd	**0,56**	**-0,50**	**0,71**	**0,61**	1	**0,65**	-0,19	0,17	0,18	0,29	-0,28	-0,27
Dl	0,40	0,34	**0,68**	**0,51**	**0,65**	1	-0,22	0,31	0,03	0,06	-0,03	-0,22
Col	-0,25	-0,05	-0,25	-0,14	-0,19	-0,22	1	0,28	0,07	0,18	0,28	-0,17
Cor	0,01	-0,30	0,09	0,18	0,17	0,31	0,28	1	-0,13	0,04	0,11	-0,10
Oid	0,38	-0,25	0,18	0,30	0,18	0,03	0,07	-0,13	1	0,12	**-0,56**	0,14
Tech	**0,65**	**-0,58**	0,28	0,25	0,29	0,06	0,18	0,04	0,12	1	-0,10	0,05
Timb	-0,41	0,32	-0,34	-0,49	-0,28	-0,03	0,28	0 ,11	**-0,56**	-0,10	1	-0,15
Graf	0,03	-0,02	-0,33	-0,32	-0,27	-0,22	-0,17	-0,10	0,14	0,05	-0,15	1

The values in bold are significative at 〈 = 0.05 (bilateral test).

Figure 1: PCA on 1-2 plane (12 criteria and 30 clones)

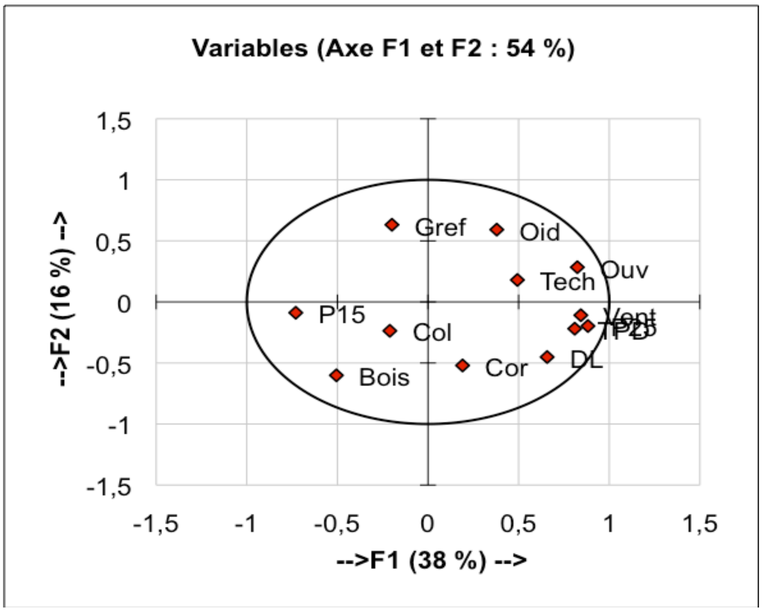

Table 3: Correlations analysis between the 12 criteria and the 4 main components

Criteria	F1	F2	F3	F4
Open	0,82	0,28	0,17	-0,28
P15	-0,73	-0,09	-0,46	0,14
P25	0,88	-0,20	-0,24	0,03
Wind	0,84	-0,11	-0,17	0,27
Tpd	0,81	-0,22	-0,12	-0,05
Dl	0,66	-0,45	-0,23	-0,18
Col	-0,21	-0,24	0,72	0,51
Cor	0,19	-0,52	0,41	0,08
Oid	0,38	0,59	0,05	0,53
Tech	0,49	0,18	0,64	-0,28
Timb	-0,51	-0,60	0,22	-0,32
Graf	-0,20	0,63	0,14	-0,42

The component F1 (38 % of the total variation contained in the matrix of the evaluations) is mainly associated with the criteria P25, Wind, Open, TPD, DL and P15. The component F2 (16 % of the variation) is mainly associated with the criteria Timb and Graf. The component F3 (13 % of the variation) is mainly associated with the criteria Col. The component F4 (9 % of the variation) is mainly associated with the criteria Oïd (table 3).

3. Multicriteria approach for the selection of rubber tree clones

The comparison and the choice of the rubber tree clones are always a multicriteria approach with evaluations that vary according to the ecological sites. Malaysia was for a long time the world leader of the production of natural rubber, and the research institute of this country (RRIM) had formalized the step leading experiments recommendations, but without clarifying the way of treating the uncertainty related to the variation of the data and the variable importance of the various criteria. Within the framework of its cooperation with the IFC (French institute of the rubber), the CIRAD (international center of agricultural research) weighted up to here the criteria in an explicit way by a method of weighted sums[13], what allowed building a global index of classification of clones without *ex aequo*.

The multicriteria method ELECTRE III (Roy B. 1978) is interesting because it allows pursuing the same objective of classification of clones by a more differentiating and different approach based on a systematic comparison of all pairs of clones.

3.1. ELECTRE III method

The multicriteria method used here is ELECTRE III (Elimination and Choice Expressing the REality) developed in the late 1970's (Roy B. 1991). This method seems to be the best one for this sort of multicriterion ranking, given the importance of the factors of imprecision, uncertainty and indetermination. It is an outranking multicriterion method, based on the concept of fuzzy logic. It allows incorporating uncertainties when evaluating the capabilities of alternative options via pseudo-criteria[14].

ELECTRE III is a multicriterion method belonging to the ranking procedure whose purpose is to rank the actions from the best to the worst. This method based on a constructive approach involving the opinion of the decision maker takes into account:

- Weighting of criteria that makes it possible for decision makers to express their opinions and their management strategies.
- Heterogeneity related with the nature of evaluations existing among criteria. This makes it difficult to aggregate all the criteria in a unique and common scale.

[13] The method of weighted sums promotes the effect of compensation between the selection criteria. According to Vincke P. (1992), the sensitivity of this method to the transformation of the scale of a criterion can be a drawback in the context of environmental management.

[14] According to Roy B. *et al*. (2005), for at least one criterion the following holds true: Small differences of evaluations are not significant in terms of preferences, while the accumulation of several small differences may become significant. This requires the introduction of discrimination thresholds (indifference and preference), which leads to a preference structure with a comprehensive intransitive indifference binary relation.

The compensation of the loss on a given criterion by a gain on another one may not be acceptable for the decision makers. Therefore such situations require the use of noncompensatory aggregation procedures.

3.1.1. Basic principle

We denote by $g_j(a)$ the valuation of the performance of the action a with respect to the criterion j. The value $g_j(a)$ of the j^{th} criterion for rubber tree selection is not exactly known. Indeed, its value is affected by three phenomena:

- Imprecision, because of the difficulty of determining it, even in the absence of random fluctuation;
- Indetermination, because its method of evaluation results from a relatively arbitrary choice between several possible definitions; and
- Uncertainty, because the value involved varies with time.

The concept of the pseudo criterion and its two thresholds allow all three phenomena to be taken into account.

3.1.2. Thresholds

With a traditional criterion g_j, knowing the sign of the difference $u = g_j(b) - g_j(a)$ is sufficient to know which of two actions is to be preferred to the other, these actions may be considered equal if u = 0. This phenomenon is called the 'true criterion' model and does not really fit well with our study. The phenomenon may, however, be studied by means of two concepts called indifference threshold (q_j) and preference threshold (p_j). These two thresholds can take into account the uncertainty existing in the analysis. Each criterion taken together with the two thresholds constitutes a pseudo criterion. This model highlights the following distinctions:

- A zone of indifference whose size depends on the value of the threshold q_j;
- Two zones of strict preference, corresponding to a difference whose absolute value is greater than the preference threshold p_j;
- Two intermediate zones representing a certain hesitation between indifference and strict preference and corresponding to an attitude described as weak preference.

Let g_j be a criterion used for comparing the performance of two actions a and b. Two cases can then arise: A greater $g_j(a)$ being better represents a a gain, or being worse represents a a loss.

3.1.2.1. Indifference threshold

"Indifference threshold of j^{th} criterion for the evaluation $g_j(a)$" is defined to be the greatest value, $q_j[g_j(a)]$, of the difference $u = g_j(b) - g_j(a)$ with $u \geq 0$, that is significant enough to differentiate a and b on this criterion. This means that, if a and b are such that $-q_j[g_j(b)] \leq g_j(b) - g_j(a) \leq q_j[g_j(a)]$ then a and b are regarded as undistinguishable by criterion g_j, because of imprecision and randomness inherent in the data and the approximation of the definition of the criterion. It is important to ensure that $\frac{q_j[g_j(b)] - q_j[g_j(a)]}{g_j(b) - g_j(a)} \geq 1$.

This condition, which is indispensable to avoid incoherence, is automatically satisfied if the thresholds are constant in absolute value or in relative value or of the form $x + yg_j(a)$ with $x > 0$ and $y > 0$.

Common sense is the predominant factor in the choice of the function $q_j[g_j(a)]$. This remark will be discussed further for each of the criteria, but let us point out here that this function has a value *0* when (as happens in the case of criterion g_3) any non-zero difference u means a variation of the preference. In the other cases, q_j can be determined by taking a positive value of u that is small enough to be insignificant and then gradually increasing u until one feels that u is at the boundary of the difference compatible with indifference between a and b for the criterion considered (Roy *et al*. 1986).

3.1.2.2. Preference threshold

When $g_j(b) > g_j(a) + q_j[g_j(a)]$, a and b are no longer indifferent with regard to criterion j. But this does not imply that there is a strict preference for a to b. This strict preference exists only when the difference u is significantly greater than $q_j[g_j(a)]$. When the values of u are too close to $q_j[g_j(a)]$, this is considered to be an ambiguous case lying between indifference and strict preference. This situation will be described as being one of weak preference.

One can start from a value of u which is being enough to ensure that there is an unquestionable strict preference, and gradually decrease $g_j(b)$ far as the particular limiting value $u = p_j[g_j(a)]$ starting from which one considers that the strict preference becomes debatable (the frontier between strict preference and weak preference). It is the adoption of this limiting value, which defines the preference threshold $p_j[g_j(a)]$. It is clear that $p_j[g_j(a)] \geq q_j[g_j(a)]$.

Equality between p_j and q_j is equivalent to n not distinguishing between the two types of situation strict preference and indifference. Let us notice that the preference threshold like the indifference one, can sometimes be constant in absolute value or in relative value, but can sometimes vary with $g_j(a)$ in a more complex way (the condition indicated above concerning the threshold if indifference must in this case be respected by the preference threshold).

3.1.2.3. Veto threshold

Another threshold, the veto threshold v_j (with $q_j \le p_j \le v_j$), can be introduced (not necessarily for each criterion g_j) in order to define the outranking relation S that incorporates all of the criteria considered. More precisely, when veto v_j is defined (i.e. $v_j \ne +\infty$) for criterion g_j, this leads to refusing the outranking of b by a when b appears sharply better than a on g_j, even if a outranks b according to all other criteria: If $g_j(b) - g_j(a) > v_j\left[g_j(a)\right]$ then we do not have aSb.

Fixing the threshold is a subjective act. These thresholds are values for assessing the appropriateness of planned action, which is required to represent approximate or arbitrary features of the data. They were defined so as to take into account directly the uncertainty that soils more or less the values of the matrix of the evaluations.

3.1.3. Credibility index

The fuzzy outranking relation seems indisputable for certain couples of actions and little convincing for others. This variation is expressed by the degree of credibility of the outranking $\delta_{a,b}$ which is a concordance index $C_{a,b}$ weakened by discordance indices $d_j(a,b)$[15]. The degree of credibility follows some qualitative principles, which exclude the possibility that a major disadvantage on one criterion might be compensated, by a number of minor advantages on other criteria.

The concordance index is calculated from the difference in performance values, q_j and p_j values, and the criteria weights w_j. The index of concordance by criterion who asserts in which measure the action a is as good at least as the action b, for the criterion j.

$$c_j(a,b) = 0 \Leftrightarrow p_j < g_j(b) - g_j(a)$$
$$0 < c_j(a,b) < 1 \Leftrightarrow q_j < g_j(b) - g_j(a) \le p_j \text{ (by linear interpolation)}$$
$$c_j(a,b) = 1 \Leftrightarrow g_j(b) - g_j(a) \le q_j$$

The index of global concordance asserts in which measure there is concordance with the hypothesis «the action a outclass the action b». It is defined $C_{a,b} = \dfrac{\sum_{j=1}^{m} w_j . c_j(a,b)}{\sum_{j=1}^{m} w_j}$. The goal of the concordance

[15] $d_j(a,b)$ contributes to this weakening if and only if it is greater to $C_{a,b}$.

concept is to use the values of indifference and preference thresholds associated with each criterion in order to characterize a group of criteria considered to be in concordance with the affirmation being studied and to assess a relative importance of this group compared with the remainder of the criteria.

Next, the other concept, discordance, is applicable to characterize which criteria are not in concordance with the affirmation under consideration. This affirmation is the one whose opposition is strong enough to reduce the credibility that would result from taking into account just the concordance. The discordance index is calculated from p_j and v_j values as well as from the difference in performance values:

$$d_j(a,b) = 1 \Leftrightarrow v_j < g_j(b) - g_j(a)$$
$$0 < d_j(a,b) < 1 \Leftrightarrow p_j < g_j(b) - g_j(a) \le v_j \text{ (by linear interpolation)}$$
$$d_j(a,b) = 0 \Leftrightarrow g_j(b) - g_j(a) \le p_j$$

Finally, the fuzzy outranking relation index (or credibility index) $\delta_{a,b}$ is given as follows. It is calculated as: For each criterion $j \in J$

$$\delta_{a,b} = \left\{ C_{a,b} \cdot \prod_{j \in J} \frac{1 - d_j(a,b)}{1 - C_{a,b}} \right\}$$

When $d_j(a,b) = 1$, it implies that $\delta_{a,b} = 0$, since $C_{a,b} < 1$.

The definition of $\delta_{a,b}$ is thus based on the following main ideas:

- When there is no discordant criterion, the credibility of the outranking relation is equal to the comprehensive concordance index.
- When a discordant criterion activates its veto power, the assertion is not credible at all, thus the index is null.
- For the remaining situations in which the comprehensive concordance index is strictly lower than the discordance index on the discordant criterion, the credibility index becomes lower than the comprehensive concordance index, because of the opposition effect on this criterion.

3.1.4. Distillation procedure and final partial pre-order

We consider all the outranking, the strongest as the weakest, by exploiting the credibility indices that are linked to it. Thus we have a rather complex graph due to the fact that each action can have more than one relation. This complexity leads us to establish two distillations so as we can get the final ranking[16]. This final ranking is a partial pre-order and the distillations are complete pre-orders. So, the final partial pre-order called *D* is built as the intersection of two variants of the same principle, both acting in an antagonistic way on the floating actions. The complete pre-order D_1 is defined as a partition on the set *A* of actions into *q* ordered classes, $\overline{B_1},\ldots,\overline{B_h},\ldots,\overline{B_q}$ where $\overline{B_1}$ is the head-class in D_1. Each class $\overline{B_h}$ is composed of *ex aequo* elements according to D_1. The complete pre-order D_2 is determined in a similar way, where *A* is partitioned into *u* ordered classes, $\underline{B}_1,\ldots,\underline{B}_h,\ldots,\underline{B}_u$ with $\underline{B}_u$ being the head-class. Each one of these classes is obtained as a final distilled of a distillation procedure.

The procedure designed to compute D_1 starts (first distillation) by defining an initial set $I_0 = A$; it leads to the first final distilled $\overline{B}_1$. After getting $\overline{B_h}$, in the distillation *h +1,* the procedure sets $I_0 = A \setminus \left(\overline{B_1} \cup \ldots \cup \overline{B_h}\right)$. According to D_1, the actions in class $\overline{B}_h$ are preferable to those of class $\overline{B}_{h+1}$; for this reason, distillation that lead to these classes will be called as descending (top-down; select as the best action to end with the worst).

The procedure leading to D_2 is quite identical, but now the actions in $\overline{B}_{h+1}$ are preferred to those in class $\overline{B}_h$; these distillations will be called ascending (bottom-up; select as the worst action to end with the best).

The partial pre-order *D* will be computed as the intersection of D_1 and D_2. A complete pre-order *D* is finally suggested taking into account the partial pre-orders and some additional considerations (Roy B. *et al*. 2005). More explicitly, this final pre-order ranks all actions in a transitive manner, with the possibility of incomparable situations (e.g. in two different distillations, a is ranked before b, but b is ranked before a in the other)[17].

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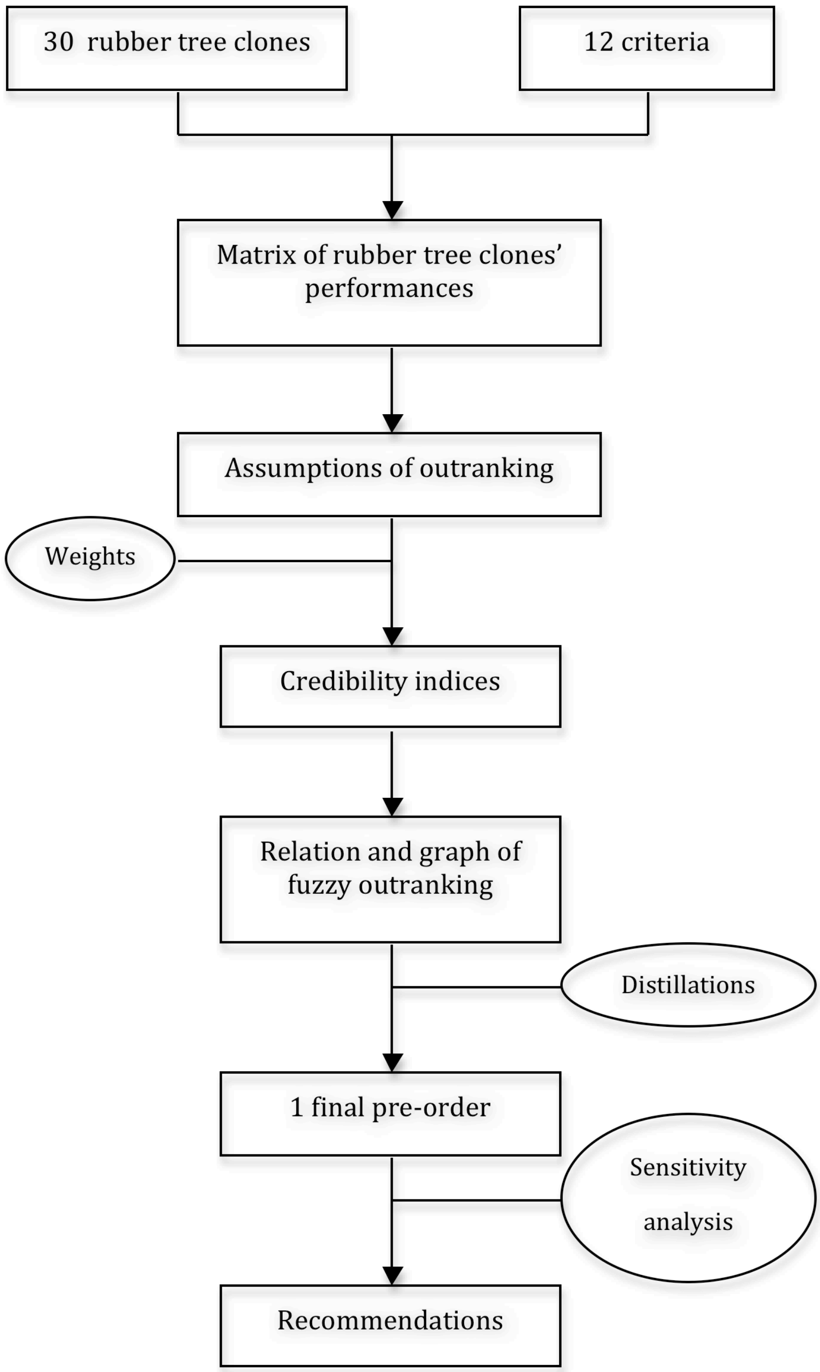
16 It is not easy to understand the principle of this complex and delicate procedure without going into details. Hence, for technical aspects of this methodology see for example Maystre et al. 1994 or Roy B., Mousseau V., Figueira J. 2005.

17 The way the incomparabilities that remain in the pre-order are treated is nevertheless subject to criticism.

Figure 2: ELECTRE III algorithm on *rubber tree* clones' selection



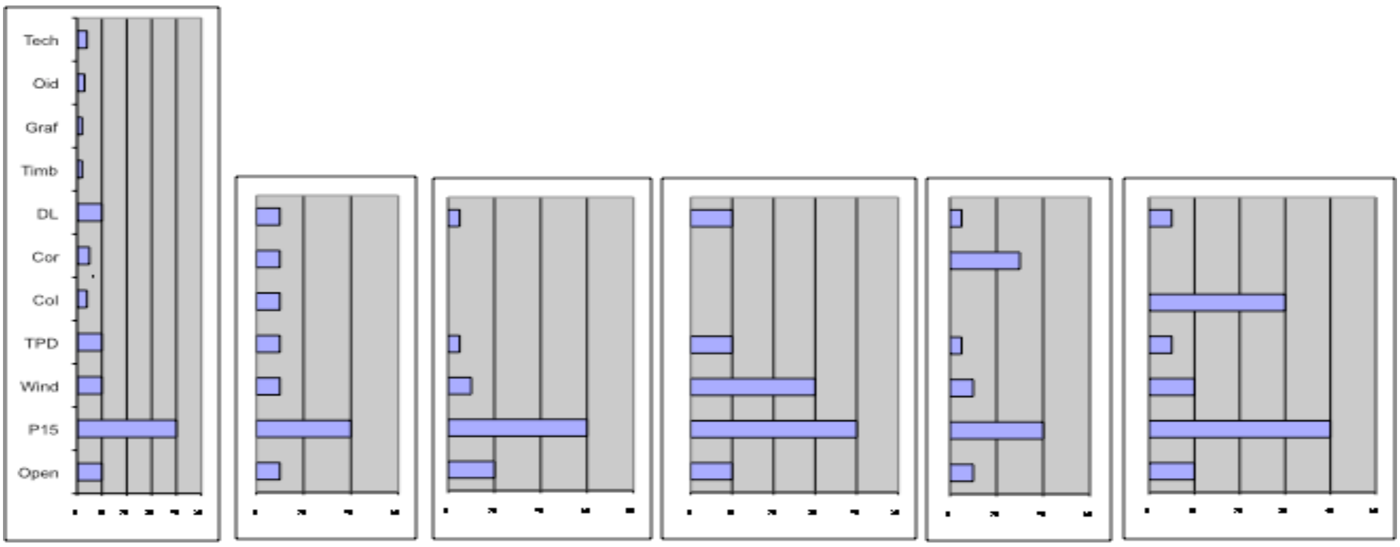
3.2. Weighting the criteria

We normalized the sum of the weights to 100 among all 11 criteria (table 4 and figure 3). The case P1 corresponds to the wish to take into account 11 criteria where the early production (Open and P15) counts for 50. In the case P2, we keep only 7 criteria (Open, P15, Wind, TPD, DL, Col and Cor) considered as the most important. In the case P3, we keep only 5 criteria linked to the production and we eliminate the criteria associated with the diseases of leaves (for the regions where these diseases are not relevant) and we increase the weights of the criteria of early production (Open and P15). In the case P4, we increased the weight of the criterion Wind (the wind has a strong incidence in Ivory Coast). In the case P5, we increased the weight of the criterion Cor (the disease corynespora has a strong incidence in Nigeria). In the case P6, we increased the weight of the criterion Col (the disease colletotrichum has a strong incidence in Gabon).

Table 4: Weights P1 to P6

	P1	P2	P3	P4	P5	P6
Open	10	10	20	10	10	10
P15	40	40	60	40	40	40
Wind	10	10	10	30	10	10
Tpd	10	10	5	10	5	5
Col	4	10				30
Cor	5	10			30	
Dl	10	10	5	10	5	5
Timb	2					
Graf	2					
Oid	3					
Tech	4					

Figure 3: Weights P1 to P6



P3 P4 P5 P6

3.3. The scenarios (S1 to S4)

The ELECTRE III method is applied to the matrix of the evaluations according to a series of different scenarios. A scenario is a complete set of parameters (weights and thresholds) chosen to describe some situation (weights of the criteria according to the ecological context, and thresholds according to the margin of error).

In a first stage, we have fixed indifference and preference thresholds to weak levels, whereas the data of evaluation are fairly precise and reproducible (table 5). We do not impose a veto threshold, thus leaving place for effects of compensation: a clone can be very inferior on a criterion and be best on the other criteria.

Table 5: Thresholds

Criteria	**Open**	**P15**	**Wind**	**Tpd**	**Dl**	**Col**	**Cor**	**Oid**	**Tech**	**Timb**	**Graf**
Indifference threshold (q_i)	1	250	1	1	1	1	1	0,5	0,5	1	0,5
Preference threshold (p_i)	3	500	2	2	2	2	2	1	1	2	1
Veto threshold (v_i)	9	2500	5	5	5	4	4				

Discrimination threshold $s(\lambda)=0,3 - 0,15\lambda$ [18]

In the second stage, we keep the weights P1 to P6 and indifference and preference thresholds already used (S1). Then we analyze the scenarios S2, S3 and S4 corresponding to an uncertainty growing on the criteria Open and P15 that we judge as the most important (table 6).

Table 6: Increasing uncertainty over the criteria « open » and « P15 », indifference and preference thresholds (q_i), (p_i).

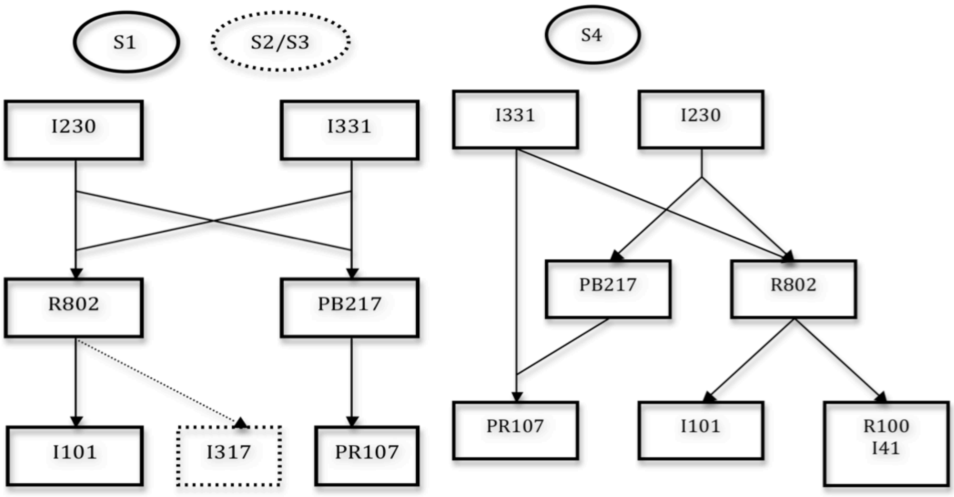
Criteria	**Open**		**P15**	
Thresholds	q_i	p_i	q_i	p_i
S1	1	3	250	500
S2	1	3	500	1000
S3	3	6	500	1000
S4	3	6	1000	2000

[18] To sort in the multitude of outranking relation, a discrimination threshold s(λ) is used to select the outranking relations that must be taken into account at each stage of the ranking. Then only the outranking whose credibility is above the threshold λ will be involved in the ranking.

4. Results

We present an example of the final outranking relations in Figure 4. This kind of graph highlights the concept of incomparability[19] and indifference. Two clones presented in the same box are indifferent; that is the case for clones R100 and I41 (in S4). Two clones without outranking relations are incomparable, as demonstrated with I230 and I331.

Figure 4: Outranking relations between rubber tree clones for P4



Another way to present the results is to use the final pre-orders from scenarios S1 to S4 (table 7 to 10). Those are ranks of clones in the sets of weights P1 to P6 when we increase the uncertainty in the analysis. The most satisfactory clones appear mainly in the first five ranks of the various rankings.

Two main situations have been developed in this study. The first one concerns the clones that could be cropped whatever the ecological constraints in Africa. This is the case for the clones I230 and I331 (ranked first and/or second in all the scenario). The second one concerns the adaptability to particular situation. This is the case for the clone GT1 with a good ability not to be affected by the *corynespora* leaf disease (set of weight P5).

Results P1 to P6 with S1 (indifference and preference thresholds initial, table 7): We have an overall stability of six rankings for each clone (a good ranking of clones GT1 in P5, PB235 in P3, PB260 in P6, a very good overall ranking of clone PR107 and a good overall level of clones PB235, I18, I19, I109, I427, I428, I523, I733, I804 and I840). We keep the same remarks for the tables 13, 14 and 15 in spite of some small differences.

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19 According to Scharlig A. (1985), these notions may seem embarrassing but they are so human. Faced with poor quality of information, the decision maker may be in those situations where it is difficult to make a choice between two alternatives.

Results P1 to P6 with S2 (increase of the uncertainty on the criterion P15, table 8): Clones I18 and I109 are less well ranked. The number of good clones decreases to 8.

Results P1 to P6 with S3 (increase of the uncertainty on the criterion Open, table 9): Clone PB235 is also well ranked in scenarios P1 and P2. The number of good clones is 6 (PB235, I427, I523, I733, I804 and I840).

Results P1 to P6 with S4 (second increase in the uncertainty on the criterion P15, table 10): The number of good clones is 3 (I427, I428 and I804).

After examining the 6 weights and the 4 sensitivities, there exists a strong similarity between rankings. But, we have surprising results, especially with clones PR107 and R712, two clones well known in Ivory Coast. Clone PR107 is very weak on criteria Open and P15 but it has a good rank in P1S1/S2. His good resistance to wind is highlighted in P4. Clone R712 has the same behaviour as PR107 (P1S4). It is unsatisfactory on Open and P15 (but less than PR107).

Table 7: Results P1 to P6 with S1

Rubber tree clones	P1	P2	P3	P4	P5	P6
GT1	11	11	14	14	4	15
PB217	**2**	**3**	**4**	**2**	**3**	**4**
PB235	9	8	3	8	6	7
PB260	12	11	10	12	10	4
PR107	3	5	7	3	5	6
R100	**3**	**2**	**4**	**5**	**2**	**3**
R600	12	14	15	12	14	14
I18	9	9	10	9	8	10
I19	4	4	9	9	9	5
I41	**3**	**3**	**3**	**4**	**4**	**5**
I101	**5**	**4**	**4**	**3**	**3**	**4**
I109	6	5	7	6	7	8
I145	11	11	9	11	9	9
I209	12	12	12	12	11	13
I230	**1**	**1**	**1**	**1**	**1**	**1**
I317	**3**	**3**	**3**	**4**	**2**	**3**
I323	11	11	12	10	11	12
I331	**1**	**1**	**2**	**1**	**1**	**2**
I427	8	8	8	7	6	7
I428	7	6	7	7	7	8
I523	5	6	5	5	4	5
I631	13	13	14	15	13	14
I733	8	7	6	8	5	6
I804	4	4	7	7	5	5
I840	7	7	6	6	5	6
PB330	10	10	9	11	8	9
PC10	13	13	13	13	12	13
R703	10	10	9	10	8	9
R712	9	9	11	6	10	11
R802	**2**	**2**	**3**	**2**	**2**	**3**

Table 8: Results P1 to P6 with S2

Rubber tree clones	P1	P2	P3	P4	P5	P6
GT1	11	10	15	14	4	18
PB217	**2**	**3**	**5**	**2**	**3**	**4**
PB235	9	8	3	8	8	8
PB260	12	12	11	14	13	4
PR107	3	5	6	3	6	7
R100	**3**	**2**	**4**	**5**	**2**	**3**
R600	12	14	16	12	17	17
I18	9	10	10	10	11	12
I19	4	4	9	9	11	5
I41	**3**	**3**	**4**	**4**	**5**	**6**
I101	**5**	**4**	**4**	**3**	**4**	**5**
I109	6	5	7	7	9	10
I145	11	12	10	13	11	11
I209	12	11	12	12	14	15
I230	**1**	**1**	**1**	**1**	**1**	**1**
I317	**3**	**3**	**3**	**3**	**3**	**4**
I323	11	11	12	11	13	14
I331	**1**	**1**	**2**	**1**	**1**	**2**
I427	8	8	8	8	8	8
I428	7	6	7	6	9	9
I523	5	6	6	5	7	7
I631	13	13	14	15	16	17
I733	8	7	5	9	6	7
I804	4	4	6	6	4	5
I840	7	5	5	4	5	6
PB330	10	10	9	11	10	11
PC10	13	13	13	14	15	16
R703	10	10	10	10	10	10
R712	9	9	11	8	12	13
R802	**2**	**2**	**2**	**2**	**2**	**3**

Table 9: Results P1 to P6 with S3

Rubber tree clones	P1	P2	P3	P4	P5	P6
GT1	11	11	17	11	4	19
PB217	**3**	**3**	**6**	**2**	**3**	**4**
PB235	4	5	4	8	7	9
PB260	12	12	13	14	13	4
PR107	4	4	7	3	6	7
R100	**2**	**2**	**5**	**5**	**2**	**3**
R600	12	14	18	11	16	17
I18	10	10	10	9	10	13
I19	5	4	12	9	10	4
I41	**4**	**3**	**4**	**4**	**5**	**6**
I101	**3**	**3**	**4**	**3**	**4**	**5**
I109	5	5	9	7	8	11
I145	12	12	11	10	11	12
I209	13	12	14	12	14	16
I230	**1**	**1**	**1**	**1**	**1**	**1**
I317	**2**	**3**	**3**	**3**	**3**	**4**
I323	11	11	12	10	13	15
I331	**1**	**1**	**2**	**1**	**1**	**2**
I427	7	7	6	5	7	9
I428	6	6	7	6	8	10
I523	5	9	7	5	6	7
I631	13	13	16	15	15	18
I733	8	8	8	8	6	8
I804	4	4	5	6	4	5
I840	6	4	5	4	5	6
PB330	11	11	11	11	10	12
PC10	14	13	15	13	15	17
R703	10	10	9	9	9	11
R712	9	9	11	7	12	14
R802	**2**	**2**	**3**	**2**	**2**	**3**

Table 10: Results P1 to P6 with S4

Rubber tree clones	P1	P2	P3	P4	P5	P6
GT1	12	14	19	14	4	16
PB217	**3**	**3**	**3**	**2**	**3**	**3**
PB235	5	10	4	8	7	7
PB260	12	14	18	16	14	5
PR107	**4**	**4**	**6**	**3**	**5**	**5**
R100	**2**	**2**	**3**	**3**	**2**	**2**
R600	13	17	20	13	16	15
I18	11	13	13	10	10	11
I19	7	5	14	11	12	4
I41	**3**	**4**	**5**	**3**	**5**	**5**
I101	**4**	**6**	**4**	**3**	**4**	**4**
I109	7	9	10	8	8	9
I145	12	14	14	13	12	13
I209	14	15	17	11	13	14
I230	**1**	**1**	**1**	**1**	**1**	**1**
I317	**3**	**5**	**2**	**4**	**3**	**3**
I323	11	13	15	12	13	12
I331	**1**	**2**	**2**	**1**	**2**	**2**
I427	7	9	7	5	6	6
I428	6	8	8	5	7	8
I523	9	11	7	6	6	6
I631	15	16	18	15	15	15
I733	10	12	9	9	7	8
I804	5	7	4	7	4	4
I840	8	10	6	7	6	7
PB330	11	15	16	14	11	13
PC10	13	14	16	12	14	14
R703	13	14	12	12	11	11
R712	3	9	11	6	9	10
R802	**2**	**3**	**3**	**2**	**3**	**3**

5. Conclusion

In this study, the multicriterion ELECTRE III method was applied to the selection of rubber tree clones to be planted in Africa. In fact, there is no method recognized today for this task; indeed agronomists rely on their knowledge to realize it. The use of ELECTRE III method in this domain is very helpful. This method allowed us to have a complete approach of the problematic of ranking rubber tree clones, without compensatory between selection criteria.

This recommendation of clones made in Africa particularly in Ivory Coast, Nigeria and Gabon, brought us to define various scenarios based on ecological constraints and opinions of decision makers.

Eleven criteria have been defined in the first step. The criteria Open and P15 considered as the most important ones have been evaluated on the basis of data coming from different plantations. The last nine other criteria have been evaluated on the basis of the knowledge of the agronomists. We have definitely set the weights and the thresholds taking into account of the different ecological constraints (such as climate, diseases, wind…) we have in African countries. ELECTRE III method allows us to do that.

We may remark few variations for the notation of the criteria “leaf disease”, “technology” and “grafting” (marks from 1 to 5). It shows us the very mild information that we can get about the behaviour of the clones with respect to those criteria. This is not the case for the other criteria “wind”, “TPD” and “DL” for which we have more information (marks from 1 to 10).

The stability of rankings in the different scenarios is an indication of the high variability among clones (56 to 90 months on Open criterion, 8556 to 23 647 kg/ha on P15 criterion, 1 to 10 on criteria wind, TPD and DL, 1 to 5 on others).

Finally, we suggest in Ivory Coast, Nigeria and Gabon the following clones: I230, I331, R802, PB217, I101, I317, R100. We can go deeper in the recommendations by giving for each of the following countries the clones that are adapted to their ecological environment:

- Clones PR107 and I41 for Ivory Coast,
- Clones GT1, I804 and I41 for Nigeria
- Clones I19, I804 and PB260 for Gabon

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